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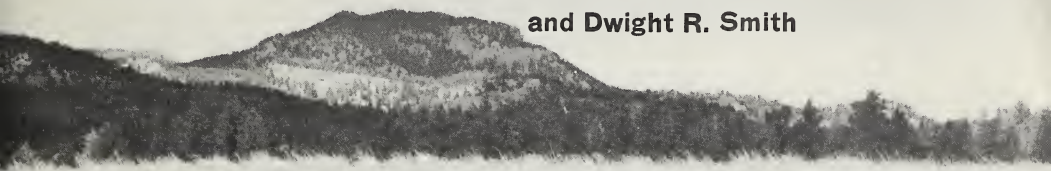

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CONTENTS

PREFACE

The authors are indebted to Dr. W. M. Johnson who conducted the grazing studies reported herein from 1946 to 1956. Dr. Johnson (1959) reported the earlier results of this study and his data, plus several years of additional research, were brought together to provide a more comprehensive evaluation of the influence of livestock grazing on several seeded species following many years of treatment. Similar long-term reports are not available and the findings reported should be of immediate and enduring value to ranchers, land managers, and others interested in the management of seeded grasses on our western rangelands.

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Pat O. Currie and Dwight R. Smith[1]

INTRODUCTION

Valleys of open grassland parks interspersed among the mountains of the ponderosa pine zone of Colorado are suitable for the production of livestock. Unfortunately, during the late 1800's and early 1900's many of these grassland parks were cultivated and attempts made to raise row crops or hay. Soil often too infertile to produce adequate yields, short growing season, erratic moisture, and the depressed economic conditions of the 1930's combined to cause many farming ventures to fail. As a result, many cultivated areas were abandoned. On others overgrazing by livestock depleted the native cover.

Natural recovery through plant succession might take many years to reach a point where good, native forage species are abundant on these lands. Seeding with introduced grasses and legumes, however, can convert depleted range or abandoned farmlands to productive range quite economically in 2 to 3 years (fig. 1).

Seeding is but the first step in restoring these lands to an early productive use. After they are seeded, proper management is necessary for their sustained use. One of the more important management factors is proper grazing intensity.

[1]Range scientist and formerly wildlife biologist, respectively, Rocky Mountain Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, with central headquarters maintained at Fort Collins in cooperation with Colorado State University. Smith is presently Assistant Professor of Wildlife Biology, Colorado State University, Fort Collins.

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FIGURE 1.—Light-colored areas in foreground and center background are occupied by low-quality vegetation typical of open grassland parks of the ponderosa pine zone which were farmed and later abandoned. The area to the left of abandoned field (center of photo) was plowed and seeded to introduced grasses the previous year.

Although several grass species are well adapted for seeding in the ponderosa pine zone, they vary in their response to grazing. This report describes the merits of several seeded species as expressed by (1) vegetative characteristics and associated range condition resulting from different intensities of grazing, and (2) the cattle weight gains associated with the use of each species.

The treatments were applied to ranges at the Manitou Experimental Forest which had been seeded to crested wheatgrass, intermediate wheatgrass, smooth brome, Russian wildrye, and a mixture of crested wheatgrass, smooth brome, and yellow sweetclover. [2] All species are adapted for seeding in the ponderosa pine zone; seeding recommendations are reported by Hull and Johnson (1955).

AREA DESCRIPTION

The Manitou Experimental Forest is located in a mountain valley of the Front Range, 28 miles northwest of Colorado Springs, Colo. The valley is paralleled by two north-south mountain ranges, the West Creek

[2]Common and scientific names of plants are listed on page 38.

Range to the west and the Rampart Range to the east. Trout Creek flows north through the valley to the South Platte River.

The Forest climate is characterized by relatively open winters and mild summers. Summer temperatures seldom exceed 90° F. Winter temperatures are often very low, reaching —40° F. Precipitation averages 15.5 inches, nearly three-fourths of which is received from April through August. As with many areas, there are wide fluctuations in both temperature and rainfall from year to year. Therefore, it is important to recognize that the influences of grazing intensity on the plant species studied may be in sharp contrast to results in other parts of the western range area with entirely different climatic conditions.

Geologically, the valley is classified as the Manitou Park Graben, which was formed by the Ute Pass Fault of the West Creek Mountains and the Devils Head Fault of the Rampart Range (Boos and Boos 1957). Alluviation, the process primarily responsible for the present land form, has left limestone and granitic rocks exposed along the steeper mountain slopes. Adjacent to the stream are flood plains of recent alluvium, and above are older deposits which ascend in gentle slopes of 5 to 20 percent to the base of the mountains. The older alluvial fans have been dissected and their material redeposited below, which has resulted in crossbedding of variouslyaged alluvium. Thus, the soils on the study sites are complex mixtures at various stages of development.

Most of the alluvial soils developed from deposits of Pikes Peak granite, and are characterized by quartz, microcline, and large orthoclase crystals with biotite or mica as the accessory mineral. Surface soils range from 8 to 10 inches thick, and contain moderate amounts of organic matter. They are slightly acid with a pH between 6.0 and 6.5, and have a moderate granular structure with soft consistency when wet, but firm when dry. Generally, the areas lack a subsoil or have a gravelly-sandy-clay loam or a coarse gravelly loam subsoil that grades into unconsolidated parent material at a depth of 3 to 4 feet.

The two sites used for the study are at an elevation of about 7,800 feet and are situated well above the flood plain on either side of Trout Creek. One, the Nursery Field, is on the east side of the creek; the other, designated as the Sinclair Field, is on the west side. Both areas were formerly cultivated fields. The Nursery Field was last plowed in 1934 for the production of oat hay. The Sinclair Field, used for both oat hay and potato production, was last cultivated in 1936.

From the time cultivation was discontinued, both areas were naturally revegetating, and at the start of the study in 1946, supported mostly low-quality annual and perennial vegetation. Lambsquarter and sunflower were the most common annuals. Fringed sagebrush, trailing fleabane, sleepygrass, tumblegrass, and hairy goldaster were among the more common perennials. Less abundant but more palatable grasses included slender wheatgrass, prairie Junegrass, bottlebrush squirreltail, and mountain muhly.

STUDY DESCRIPTION

Pasturing Systems

Species Establishment and Grazing Treatments

Crested wheatgrass, smooth brome, and a mixture of 40 percent crested wheatgrass, 40 percent smooth brome, and 20 percent yellow sweetclover were planted separately at the Nursery and Sinclair locations in the spring of 1946. Intermediate wheatgrass and Russian wildrye were planted in the spring of 1948 and 1949, respectively. The species were planted in 10-acre blocks. At each location, the 10-acre block of each species was subdivided into a 5-acre unit for an intermediate rate of grazing, a 3-acre unit for a lighter grazing rate, and a 2-acre unit for a heavier grazing rate (fig. 2). Grazing treatments began in the spring of 1948 on the species planted in 1946, in 1950 on intermediate wheatgrass, and in 1951 on Russian wildrye.

After 5 years of grazing, an additional treatment of heavier grazing was superimposed on the crested wheatgrass, smooth brome, and mixture.

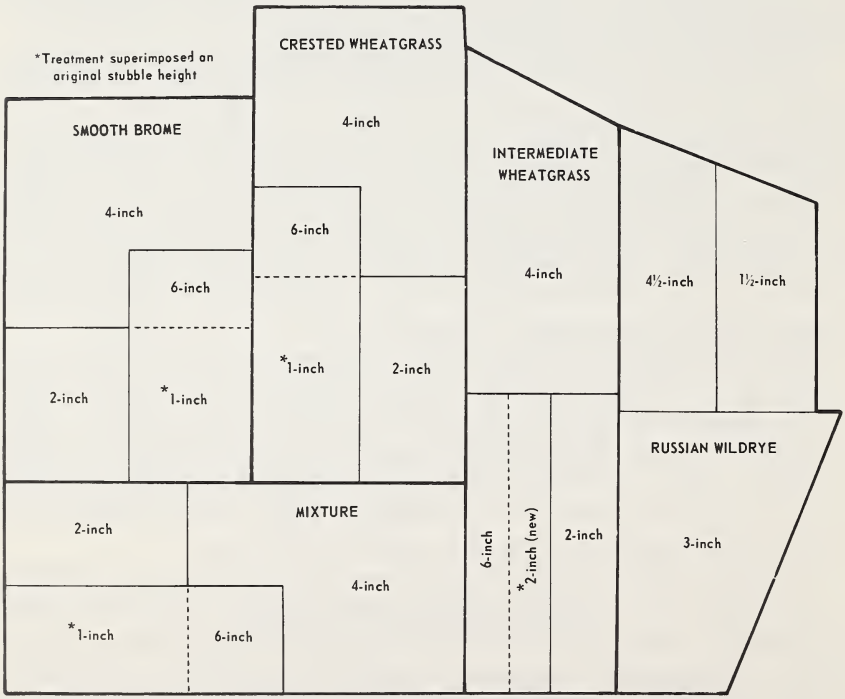

FIGURE 2.—Arrangements of grazing treatments for seeded ranges on the Nursery Field, Manitou Experimental Forest. A similar arrangement was used at the Sinclair location. Utilization treatments are shown as stubble height at end of season.

The 3-acre unit was subdivided—1 acre remained under the lightest stocking and 2 acres were grazed heavily.

Grazing to a 2-inch stubble had an observable influence on intermediate wheatgrass following only 4 years of grazing. To more thoroughly evaluate this level of use, a second test of grazing to 2-inch stubble height was established in 1954. In each block, the 3-acre units were subdivided into 1.5-acre units and grazing continued on half the unit at the lightest rate, while the other half was grazed at the 2-inch rate. This treatment is referred to as the "new" treatment to distinguish it from the original. Units in the Russian wildrye were not altered during the study and were 3, 5, and 2 acres, respectively, for the lightest to heaviest intensity.

Utilization Measurements

Degree of use was based on average stubble heights of each species at the end of the grazing season. Except for Russian wildrye, the stubble height objective was 6 inches for the lightest grazing treatment, 4 inches for the intermediate, 2 inches for the initial heaviest, and 1 inch for the most heavily grazed treatment superimposed later. For Russian wildrye, 4.5, 3, and 1.5 inches were the respective stubble height objectives. Russian wildrye was grazed at these three different stubble height intensities throughout the study.

Initially, 30 randomly located plants were measured in each unit to estimate utilization; after 1956, 60 plants were measured. Because degree of utilization is usually expressed in percent of weight removed, average stubble height for each treatment was converted to percent utilization through use of height-weight curves for each species (Lommasson and Jensen 1943). For all species except Russian wildrye, the values averaged approximately 33 percent under 6-inch treatment, 45 percent under 4-inch, 65 percent under 2-inch, and 80 percent under 1-inch treatment. Utilization of Russian wildrye was 11, 20, and 41 percent, respectively, for 4.5-, 3.0-, and 1.5-inch treatments.

Season and Stocking

Grazing of each species began when maximum leaf lengths in the lightest grazed units averaged 4 inches. For the mixture, leaf lengths of smooth brome were used as the "on" date criteria through 1953. Thereafter, leaf lengths of crested wheatgrass had to be used. Dates for stocking the pastures varied since "on" dates were determined by leaf lengths of individual species and "off" dates by utilization objectives. If regrowth occurred after animals were removed from the pastures, they were returned to graze the units until the respective stubble heights were again reached. Regrowth was considered sufficient for putting animals back "on" when leaf lengths were approximately 2 inches taller than the stubble height objective for any given treatment. Thus, the periods of

grazing within a season varied from year to year for each species. In some years, grazing was continuous from spring until fall. Most years, however, were split into a rather long, spring-early summer grazing season and a shorter fall period.

Yearling Hereford heifers, representative of commercial herds in the surrounding area, were furnished by local stockmen a few days prior to the start of the grazing season each year. Animals were usually in medium condition for overwintered cattle. Weights averaged 410 pounds but varied from year to year. The heifers were weighed at the beginning and end of the grazing season, except during split seasons when they were weighed at the start and end of each period. Animals were weighed after an overnight shrink without feed or water.

At the start of the grazing season, two heifers were put in a unit used at the intermediate rate and two in a most lightly grazed unit. Thereafter, all animals were rotated at weekly intervals in such a way that two heifers were on the intermediate units throughout the season. The lightest and heaviest used areas received alternating weekly rests. This stocking procedure was used on Russian wildrye throughout the study. For crested wheatgrass, the mixture, and smooth brome, the stocking system was applied through the 1952 grazing season, and for intermediate wheatgrass through the 1953 grazing season.

A new stocking system was devised to maintain stubble height utilization objectives when units to be grazed to the 1-inch stubble or, in the case of intermediate wheatgrass, the second 2-inch treatment, were fenced out from the 6-inch treatment units. Two heifers were placed in the 6-inch treatment units for 2 days every other week, and they spent the remaining 5 days in the units grazed to 2 inches. Then, on alternate weeks the areas to be grazed to 1 inch were grazed the full 7 days. Again, the rotation was such that two heifers were on 4-inch treatment for the duration of the grazing season. Since animals were rotated among units within a species, weight gain comparisons were possible among species but not treatments. The animal days of grazing that each treatment supported were compared, however.

Plant Measurements

Vigor

Leaf lengths measured to determine the start of the grazing season each year were also used as an expression of plant vigor. The maximum leaf height on 30 plants was measured along several pace transects located at random within each unit. The measurements were made from ground level at the crown to the tip of the longest blade. When maximum leaf length for 30 plants of a species averaged approximately 4 inches in the lightest grazed units, measurements were taken in the other units to obtain comparative estimates of vigor.

Forage Production

Forage production was sampled each year throughout the study. Four small, portable wooden exclosures or wire cages excluded animals in each unit. These exclosures were put in place before grazing started and moved and randomly located each year. Herbage was harvested when plants reached their maximum production and again when grazing ended in those years of season-long grazing. In years with split seasons, plants were clipped to ground level at the end of each grazing period, then bagged, dried, and weighed. Production was determined on an air-dry basis.

Following termination of the grazing phase of the study in 1959, forage production was sampled more intensively during the growing season of 1960. Twenty-five 9.6-square-foot plots were used to sample production in each unit by the double sampling technique (Wilm et al. 1944). Plots were randomly located and arbitrarily divided into groups of five. Yield was estimated on each plot of a group; then one plot was randomly selected and current year's growth clipped to ground level. The clipped forage was weighed immediately and again after the sample had been air dried. Green forage weights were used in the regression analysis to adjust the estimate data. Adjusted weights were converted to an air-dry basis for comparison with previous years' forage production.

Density, Cover, and Morphological Attributes

In addition to forage production, other vegetative characteristics were intensively sampled in 1960. Although these measurements were not taken at the start of the study, it was believed they would help characterize the influence of grazing treatments on each species, and reflect the cumulative response to treatment. Several methods were used to make this evaluation. The method selected depended upon morphology and other characteristics of the individual species.

Density.—The numbers of individuals of each seeded species, as well as other plants invading the stands, were determined on list-count quadrats (Oosting 1953). Two contiguous placements of a 1- by 10-foot metal quadrat frame delineated a plot. Ten randomly located plots were counted within each unit. For the bunchgrass species, only plants with more than half their basal areas within the frame were included in the counts. Plants were counted as individuals if more than 1 inch of bare ground occurred between crown segments. Otherwise, aggregate clumps were counted as one plant. For the two rhizomatous species, individual stems were counted as separate plants if they were separated from the parent plant by 1 inch or more.

Cover.—Ground cover characteristics, including an index of basal area occupied by seeded and invading species, were estimated on all units from vertical point quadrats (Clark et al. 1942). Observations were made using a quadrat frame with twenty 18-inch pins spaced 2 inches apart placed along a taut cable stretched between the same transect stakes used for the list-count quadrat. The point frame was reset five times along each 1- by 20-foot transect to provide an evaluation based upon 1,000 points in each treatment.

Morphological attributes.—Basal diameters or plant size and tiller densities of Russian wildrye and crested wheatgrass seeded singly and in the mixture were measured with specially devised "tiller counters" (fig. 3).

Plant size was determined by inserting the tiller counter through the widest portion of the plant crown at the soil surface. It was placed at right angles to the cable at the widest segment of an intercepted plant; diameter was recorded to the nearest 0.20 inch. Tillers within the frame were counted and converted to number of tillers per square inch.

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FIGURE 3.—Measuring plant diameter and counting number of tillers by inserting a specially devised "tiller counter" through the plant crown at right angles to the transect line. The tiller counters were constructed by bending 3/16-inch-square steel stock to form a rectangle open at one end. The rigid frames, 0.5 inch wide by either 6 or 12 inches long, were marked with 0.20-inch graduations along the long axis to facilitate counting and measuring.

RESULTS AND DISCUSSION

Forage Production in Relation to Precipitation

Except for Russian wildrye, forage production on seeded ranges was greatest the third growing season following planting. Russian wildrye required five growing seasons to reach its highest production (fig. 4). Once the maximum was reached, forage production of all species decreased sharply and then fluctuated from year to year. Precipitation during the growing season from April through August, rather than grazing treatment, accounted for most of the annual variation.

After the first 3 years, maximum and minimum production of crested wheatgrass and the mixture coincided with the extremes in growing-season precipitation. Crested wheatgrass within all treatments averaged 593 pounds per acre in 1951 when precipitation was only 5.71 inches, but 1,697 pounds in 1957 with 15.62 inches of moisture. Production of the mixture was 554 and 2,184 pounds during these same 2 years. The correlation coefficient between the air-dry forage produced by these species and growing-season precipitation was 0.787 for crested wheatgrass and 0.822 for the mixture ranges. Both coefficients were significant.

Production of intermediate wheatgrass and smooth brome was significantly correlated with precipitation, but both species tended to go out of the stands under all grazing intensities. Early in the treatment period, high moisture in a year such as 1953 stimulated forage production; by 1957, however, these two species responded only temporarily to favorable moisture but continued their progressive decline under grazing. Because of this grazing effect, average forage production of intermediate wheatgrass decreased from 1,252 pounds per acre in 1953 to 298 pounds in 1960 and smooth brome ranged from 1,045 to 218 pounds per acre in these same years.

Russian wildrye attained a peak production of 1,683 pounds per acre in 1953 when growing-season moisture was 12.22 inches. Forage production was 1,199 pounds per acre in 1957 when growing-season moisture was 15.62 inches. The low of 442 pounds per acre occurred in 1960 when rainfall was only 6.69 inches. Similar to each of the other species, production was significantly correlated with April-through-August moisture.

Effects of Grazing Treatments on Individual Species

Crested Wheatgrass

Forage production.—In 1960, or after 7 to 12 years of grazing, forage production of crested wheatgrass was reduced 10 percent or less between each successive increase in grazing intensity (table 1). When yields were

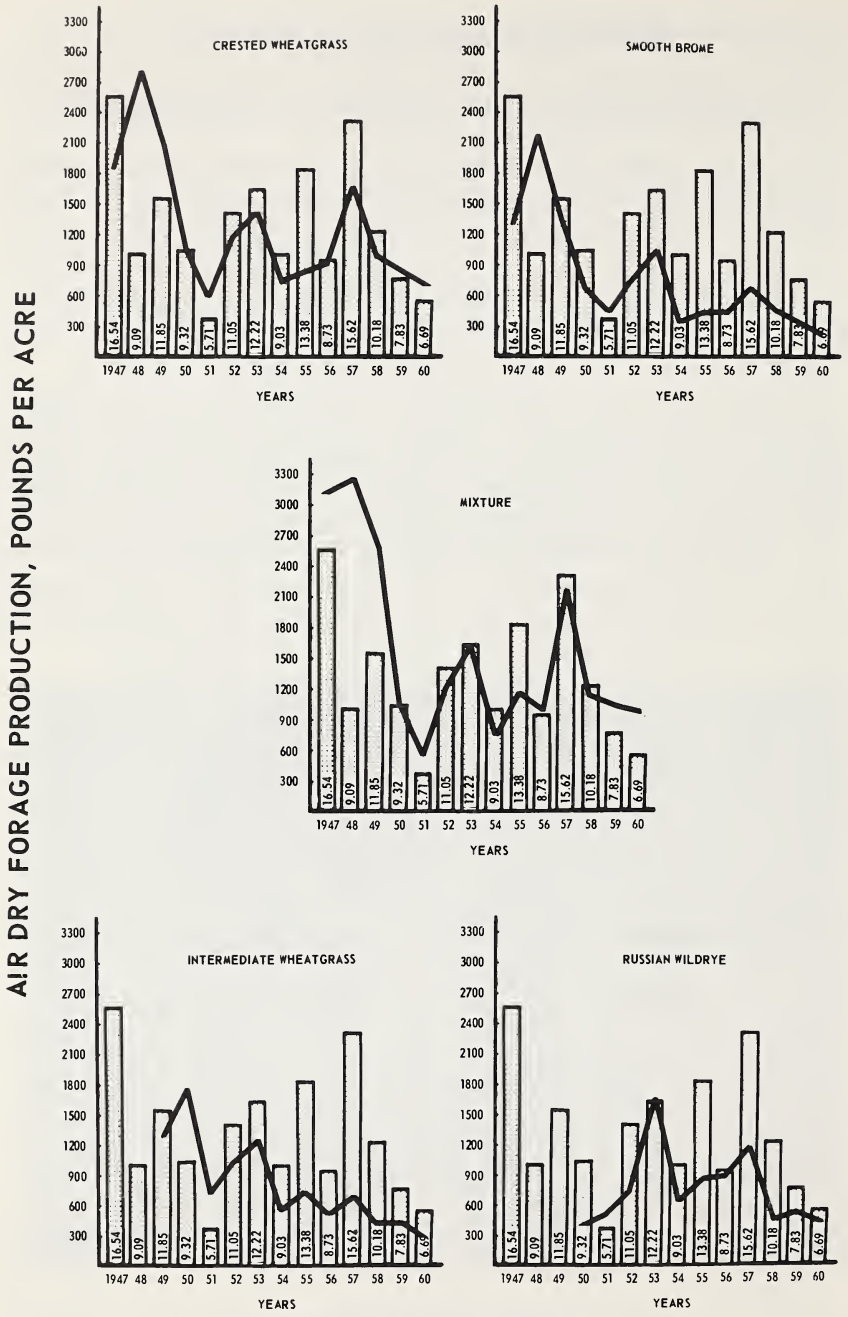

FIGURE 4.—Average forage production of seeded ranges for all intensities of grazing in relation to April 1 through August 31 precipitation (vertical dotted bars show inches of precipitation).

considered for all years, however, the units grazed to a 1-inch stubble produced an average of about 300 pounds per acre less forage than those grazed to 4- or 6-inch stubbles. On the other hand, there was less than 100 pounds difference in average forage production between units grazed to 2 inches and those grazed to 4 or 6 inches. In addition, in 1952, 1953, 1955, 1957, and 1958, when moisture was near or above average, production on units grazed to either a 1- or 2-inch stubble height was comparable to or exceeded that from units grazed to 4 or 6 inches.

TABLE 1.—*Air-dry yields of crested wheatgrass under four intensities of grazing, by stubble heights and percent utilization,* [1] *Manitou Experimental Forest, 1948-60*

Year	Yields by grazing intensities (stubble heights)				
	1 inch (81 percent) [1]	2 inches (67 percent) [1]	4 inches (46 percent) [1]	6 inches (31 percent) [1]	Average
			Pounds per acre		
1948	—	2,862	3,279	2,300	2,814
1949	—	2,025	1,902	2,347	2,091
1950	—	964	1,045	1,202	1,070
1951	—	536	618	626	593
1952	—	1,210	1,138	1,237	1,195
1953	1,513	1,085	1,422	1,691	1,428
1954	494	579	848	986	727
1955	893	957	828	776	864
1956	807	850	952	1,083	923
1957	1,644	1,848	1,895	1,399	1,697
1958	1,051	1,050	933	944	994
1959	701	885	890	987	866
1960	644	692	762	848	736
Average	968	1,196	1,270	1,264	1,174

[1]Percentage of forage removed by weight, averaged for all years.

Although production was less at the heavier rates of use in the drier years, the amount of forage used by the cattle was similar under all grazing intensities (fig. 5). Under more favorable moisture conditions (such as in 1957), the amount of forage grazed on the 1- or 2-inch treatments was several hundred pounds more than that grazed from the 4- or 6-inch treatments. Also, plants were grazed uniformly at the two heavier rates, but grazing was *not* uniform at the two lightest intensities of use. On these treatments, plants once grazed continued to receive heavy grazing throughout each season and in successive years. As a result of this difference in grazing pattern, a patchwork of "wolf plants" developed. Much of the forage produced on the units grazed to 4 inches, and particularly those grazed to 6 inches, was left untouched.

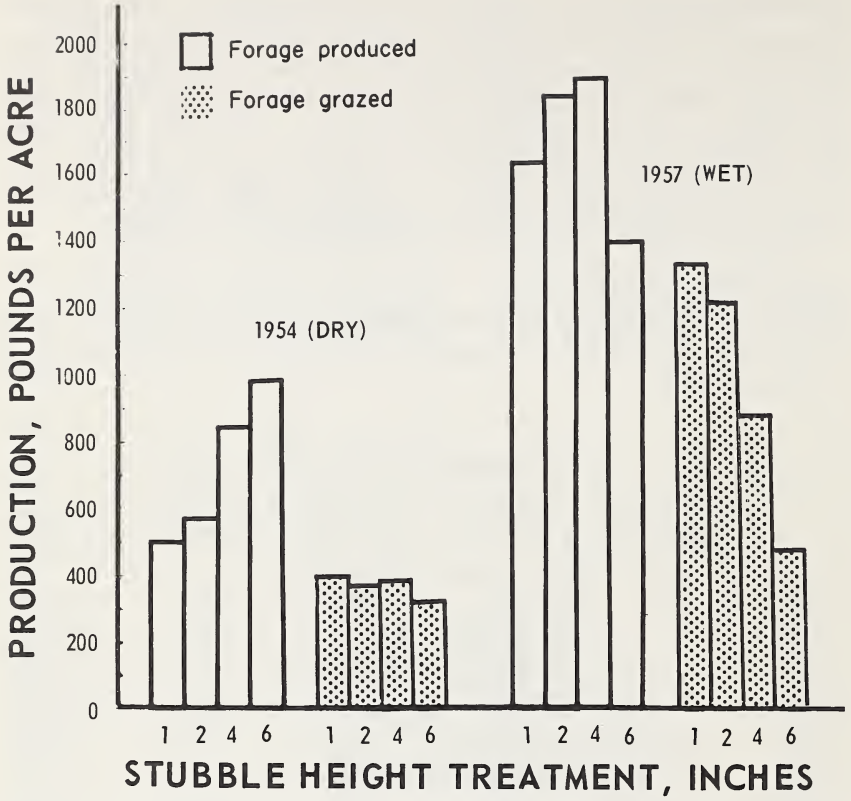

Figure 5.—Forage production of crested wheatgrass in relation to forage grazed under different intensities of use during low moisture in 1954 and good moisture in 1957.

Stand characteristics.—Leaf lengths of crested wheatgrass at the beginning of the grazing season were also reduced by the 2-inch and 1-inch grazing treatments. For example, in 1953, when grazing to a 1-inch stubble height was superimposed on a portion of the units previously grazed to a 6-inch stubble height, leaf lengths were 5.2 inches. By 1955, after 2 years of very heavy grazing, leaf lengths averaged 3.2 inches on units grazed to a 1-inch stubble height compared to 4.0 inches on the units grazed to a 6-inch stubble height.

Apparently, reduction in height growth did *not* affect yields. As shown in table 1, forage production from either the 1-inch or 2-inch grazing treatments in 1955, 1957, or 1958 was comparable to or exceeded production from the more lightly grazed ranges by several hundred pounds. This occurred although leaf lengths on the two heaviest grazed units became progressively shorter at the start of grazing each year and were shorter than those on 4-inch or 6-inch treatments from 1955 to 1968 (table 2).

TABLE 2.—*Leaf length* [1] *of crested wheatgrass as related to grazing at four intensities (stubble heights)*

Grazing treatment (stubble height)	Leaf length (inches)								
	1950	1951	1952	1953	1954	1957	1958	1959	Average
1 inch	—	—	—	5.2	3.2	3.2	2.9	2.5	3.4
2 inches	4.0	3.9	3.9	4.6	3.7	3.3	3.2	2.9	3.7
4 inches	4.5	4.4	4.1	5.1	4.0	3.8	3.9	3.4	4.2
6 inches	4.6	4.4	4.3	5.2	4.0	3.6	4.0	3.8	4.2

[1]Leaf lengths were measured at beginning of grazing season, and used as indicators of relative plant vigor.

When measurements were made in 1960 to evaluate the cumulative effect of past grazing treatments, the numbers of crested wheatgrass plants and tillers per square inch of plant were larger but basal diameters of individual plants were smaller as a result of each increase in grazing intensity (table 3). The largest difference in plant density was between the 6-inch and 4-inch stubble height treatments; plant densities were 10 percent greater on the 4-inch treatment than on the 6-inch treatment. Otherwise, the increase in density was less than 6 percent between each successive increase in grazing use.

Although the numbers of plants and tillers were smallest on units grazed to a 6-inch stubble, basal diameter of the individual crested wheatgrass plants was largest on these units and exceeded diameters for the other treatments by more than 0.5 inch. It was characteristic of crested wheatgrass at the heavier rates of grazing to fragment into more numerous clumps with smaller basal diameters but with a greater production of tillers from the basal nodes. Springfield (1963) obtained similar results from grazing intensity studies on crested wheatgrass in New Mexico.

TABLE 3.—*Stand characteristics of crested wheatgrass and invading native species in 1960 after grazing at four intensities: 1-inch stubble height for 7 years; 2-inch, 4-inch, and 6-inch stubble heights for 12 years*

Grazing treatment (stubble height)	Crested wheatgrass			Invading species			
				Fringed sagebrush	Other grasses	Forbs	Total
	Plant density	Basal diameter	Tillers	Plant density			
	No./sq. ft.	*Inches*	*No./sq. inch*	*No./sq. ft.*			
1 inch	2.93	2.90	7.90	1.18	0.34	0.07	1.59
2 inches	2.82	2.94	7.54	2.12	.21	0	2.33
4 inches	2.66	2.89	6.68	1.36	.28	.70	2.34
6 inches	2.41	3.56	6.45	.58	.23	.04	.85

The total number of native plants that invaded the crested wheatgrass stands did *not* show a definite trend in relation to treatment. Units grazed to a 6-inch stubble height had the smallest number of invaders, but units grazed to 4 inches were invaded most (table 3). On the former, the larger and more vigorous plants in ungrazed patches kept invasion to a minimum. Heavily grazed spots in this treatment though were invaded like the more heavily grazed units. In all cases, most of the species invading crested wheatgrass stands were undesirable. Fringed sagebrush was the primary invader and with the forb, trailing fleabane, contributed approximately 75 percent to invasion of the stands.

By 1960, the most important feature of cover changes on the units was the differences in litter and crested wheatgrass. Litter averaged 25, 30, 36, and 36 percent, respectively, in the 1-, 2-, 4-, and 6-inch treatments, or a difference of 6 to 11 percent between the two heaviest and two lightest intensities. Basal cover of crested wheatgrass also averaged 3 to 9 percent less on the two more heavily grazed treatments with the 9 percent decrease occurring on the 1-inch treatment. There were relatively small differences of 2 percent or less in cover of invading species between the four treatments.

These results, in conjunction with those of forage production and plant vigor, indicated grazing to a 2-inch stubble height, or approximately 65 percent use of the forage, was *not* detrimental to crested wheatgrass on a sustained yield basis. At this rate of use over a period of years, plants will fragment into smaller but more numerous clumps with a small decrease in plant height, forage production, and litter cover. However, use of the forage available at the 2-inch level will be larger and grazing more uniform than with lighter use. In years of good moisture, the ranges grazed to 2 inches will produce more available forage than those grazed at a lighter rate. Although density was similar to the 2-inch stubble height, grazing to a 1-inch height was *not* justified when the additional reduction in litter, crested wheatgrass cover, and over 200 pounds per acre in average forage yield were considered.

Smooth Brome

Forage production.—Smooth brome did *not* hold up well under *any* intensity of cattle grazing. Although Hull and Johnson (1955) found this species well adapted and long lived when left ungrazed in nursery trials, it was affected detrimentally by even the lightest level of grazing. For example, at the start of the study in 1948, production of smooth brome was similar in all units and averaged 2,161 pounds per acre. By 1960, production averaged 218 pounds per acre, and there was a difference of only 20 pounds per acre between the three original treatments (table 4). Superimposing the 1-inch treatment on a portion of the areas grazed to

a 6-inch stubble had very little additional effect in lowering production. After 7 years of treatment, forage yields from these units grazed to 1 inch averaged only 46 pounds per acre less than for those grazed to 6 inches.

Smooth brome yields decreased rapidly from all intensities of use. In 1949, the second year after grazing started, the amount of forage produced averaged a little more than half of what it did in 1948. By 1950, average forage production was approximately 30 percent of the 1948 yields. As pointed out previously (fig. 4), forage production at all intensities of use would increase somewhat in very favorable moisture years such as 1953 or 1957. This response was temporary, however, and with average or below average moisture, production decreased appreciably.

TABLE 4.—*Air-dry yields of smooth brome under four intensities of grazing, by stubble heights and percent utilization,* [1] *Manitou Experimental Forest 1948-60*

Year	Yields by grazing intensities (stubble heights)				
	1 inch (78 percent) [1]	2 inches (61 percent) [1]	4 inches (41 percent) [1]	6 inches (31 percent) [1]	Average
			Pounds per acre		
1948	—	2,274	2,096	2,114	2,161
1949	—	1,330	1,432	1,162	1,308
1950	—	627	734	647	669
1951	—	410	470	443	441
1952	—	596	832	820	749
1953	884	981	975	1,404	1,061
1954	261	259	454	459	358
1955	428	264	548	531	443
1956	378	352	539	497	443
1957	555	654	726	853	697
1958	446	474	457	504	470
1959	361	309	308	572	388
1960	176	232	242	222	218
Average	436	674	755	787	663

[1]Percentage of forage removed by weight, averaged for all years.

Stand characteristics.—Vigor, density, and amount of ground cover of smooth brome decreased with each increase in grazing intensity (table 5). In addition, all treatments had about the same density of undesirable species, primarily fringed sagebrush (table 5) and trailing fleabane. Therefore, these measurements (as with forage production) show smooth brome is *not* suitable for seeding in pure stands in the pine zone. However, it is well established that this species requires good soil fertility, and the possibility exists that grazing in combination with low fertility may have a more severe effect than grazing alone on more fertile soils.

TABLE 5.—*Stand characteristics of smooth brome and invading native species in 1960 after grazing at four intensities: 1-inch stubble height for 7 years; 2-inch, 4-inch, and 6-inch stubble heights for 12 years*

Grazing treatment (stubble height)	Smooth brome			Invading species			
				Fringed sagebrush	Other grasses	Forbs	Total
	Vigor[1] (Leaf length)	Plant density	Ground cover	Plant density			
	Inches	*No./sq. ft.*	*Percent*	*No./sq. ft.*			
1 inch	3.1	3.88	2.30	3.47	0.94	1.00	5.41
2 inches	3.2	4.08	3.45	3.54	.51	1.05	5.10
4 inches	3.8	4.25	3.55	2.20	.40	2.65	5.25
6 inches	4.1	5.67	3.85	3.45	.68	1.29	5.42

[1]As measured by leaf length. Average for 1950-59, except the 1-inch treatment, which is average for 1953-59.

Mixture

Forage production.—A mixture of crested wheatgrass, smooth brome, and yellow sweetclover outproduced the units on which the grass species were seeded alone under all levels of grazing (table 6; see also tables 1 and 4). Although sweetclover had largely disappeared from the stands by 1949, the benefits from the increased nitrogen fertility provided by this species presumably persisted for several years. Whether this enhanced rooting characteristics and more efficient use of available moisture is not known. However, there were definite differences in the morphology of crested wheatgrass plants between the mixture and pure stands. Plants in the mixture were much more robust with greater numbers of leaves which resulted in larger forage yields. Otherwise, the response of individual plants in the mixture to different grazing intensities was similar to responses for crested wheatgrass and smooth brome seeded in pure stands.

Forage production of smooth brome in all treatments of the mixture was similar to that of crested wheatgrass in 1950 (table 6). By 1951, forage production of smooth brome in each treatment was only about a fourth of that produced by crested wheatgrass. Except for minor increases with more favorable precipitation, smooth brome continued to decrease. By 1959, the year grazing terminated, production of smooth brome averaged only 26 pounds per acre compared to 1,014 pounds per acre for crested wheatgrass. On the units grazed to 2 or 4 inches, essentially no smooth brome was produced.

The rapid depletion of smooth brome in the mixture stands at all levels of use resulted from two interacting factors: (1) Sensitivity of smooth brome on these low fertility sites to grazing, and (2) the difference in

TABLE 6.—*Air-dry yields of crested wheatgrass and smooth brome on mixture pastures under four intensities of grazing, by stubble heights and percent utilization,* [1] *Manitou Experimental Forest, 1948-60*

Year and species	Yields by grazing intensities (stubble heights)						
	1 inch (82 percent) [1]	2 inches (65 percent) [1]	4 inches (46 percent) [1]	6 inches (35 percent) [1]	Averages for— wheatgrass	brome	combined [2]
	Pounds per acre						
[2]1948	—	3,624	3,552	2,542	—	—	3,239
[2]1949	—	2,017	2,801	2,938	—	—	2,585
1950							
wheatgrass	—	415	651	497	521		
brome	—	512	469	520		500	
1951							
wheatgrass	—	377	487	416	426		
brome	—	113	116	152		127	
1952							
wheatgrass	—	1,006	1,292	976	1,091		
brome	—	115	92	187		131	
1953							
wheatgrass	1,730	1,130	1,446	1,350	1,414		
brome	134	268	129	316		212	
1954							
wheatgrass	482	590	834	888	698		
brome	31	24	4	65		31	
1955							
wheatgrass	1,038	1,125	1,160	1,266	1,147		
brome	24	29	19	75		37	
[2]1956	733	855	1,200	1,202	—	—	998
1957							
wheatgrass	1,794	2,186	2,695	1,870	2,136		
brome	49	13	0	127		47	
1958							
wheatgrass	813	1,082	1,196	1,304	1,099		
brome	22	2	6	108		34	
1959							
wheatgrass	680	918	1,208	1,250	1,014		
brome	58	1	0	46		26	
[2]1960	750	950	1,154	1,128	—	—	996
Average							
wheatgrass [3]	1,090	981	1,219	1,091	1,095		
brome [3]	53	120	93	177		111	
combined, all years	1,042	1,335	1,578	1,479			1,358

[1]Percentage of forage removed by weight, averaged for all years.
[2]Species not recorded separately in 1948, 1949, 1956, and 1960.
[3]For years 1950-55, 1957-59, when species were recorded separately.

palatability between crested wheatgrass and smooth brome. In the mixture stands, cattle preferred smooth brome over crested wheatgrass and usually grazed it closer in all treatments (table 7).

Forage production of crested wheatgrass was usually greater in the mixture than in comparably grazed stands of crested wheatgrass (table 6; see also table 1). In addition, there was a greater difference in the forage produced between treatment extremes in the mixture stands. For example, in 1960 forage production was highest in the 4-inch stubble height treatment and averaged 1,154 pounds per acre. It was 204 pounds per acre less on units grazed to 2 inches and 404 pounds per acre less on those grazed to 1 inch. In some years, differences between treatments were even larger than these, and over the study period, units grazed to 2 inches produced about 250 pounds less forage than those grazed to 4 inches, while the units grazed to 1 inch produced about 550 pounds less forage.

TABLE 7.—*Comparison of stubble heights of crested wheatgrass and smooth brome in the mixture pastures, 1949-54*

Species and grazing treatment (stubble height)	Actual grazing intensity (stubble height)						
	1949	1950	1951	1952	1953	1954	Average
Crested wheatgrass:				*Inches*			
1 inch	—	—	—	—	1.1	1.1	1.1
2 inches	2.2	2.2	2.0	2.2	2.3	2.1	2.2
4 inches	4.2	4.3	4.4	4.7	4.5	4.0	4.4
6 inches	7.5	6.3	6.0	6.7	6.7	5.8	6.5
Smooth brome:							
1 inch	—	—	—	—	.9	1.0	1.0
2 inches	1.8	2.1	2.2	1.3	1.8	1.6	1.8
4 inches	3.8	4.0	3.8	1.9	3.8	3.6	3.5
6 inches	3.2	5.8	4.5	2.3	3.8	4.2	4.0

Stand characteristics.—As in stands seeded *only* to crested wheatgrass, grazing was uniform on the mixture units grazed to 1- and 2-inch stubble heights. On these units, animals made better use of the forage, and ungrazed wolf plants did *not* develop as they did on the two more lightly used units.

Smooth brome nearly disappeared under all grazing intensities, but this apparently had little influence on invasion by other species. Fringed sagebrush was again the most abundant invader. On the 1-inch stubble height treatment, density of this species was about three times as great as on the other treatments; considerably more forbs also invaded the very heavily grazed units (table 8). Otherwise, invasion of the mixture was quite similar for the 2-, 4-, and 6-inch stubble height treatments. In comparison to the other seeded ranges, invasion by undesirable species was generally less.

TABLE 8.—*Stand characteristics of seeded species and invading native species on the mixture pastures in 1960 after grazing at four intensities: 1-inch stubble height for 7 years; 2-inch, 4-inch, and 6-inch stubble heights for 12 years*

Grazing treatment (stubble height)	Seeded species		Invading species				Crested wheatgrass	
	Crested wheatgrass	Smooth brome	Fringed sagebrush	Other grasses	Forbs	Total	Basal diameter	Tillers
	Plant density							
	No./sq. ft.						*Inches*	*No./sq. inch*
1 inch	2.29	0.16	2.66	0.17	0.33	3.16	2.57	9.43
2 inches	2.27	.04	.85	.22	.02	1.09	3.22	7.96
4 inches	1.76	.02	.40	.12	.01	.53	3.75	6.51
6 inches	1.83	.20	.90	.12	.06	1.08	3.99	6.60

The outstanding feature of the mixture pastures, regardless of treatment, was their conversion to nearly pure stands of crested wheatgrass and the difference in morphology of the plants. Crested wheatgrass density on comparable treatments averaged from 20 to 34 percent fewer plants per square foot on the mixture than on the areas seeded only to crested wheatgrass, but basal diameters of plants and the number of tillers per plant tended to be larger in the mixture (table 8). Thus, like crested wheatgrass planted in pure stands, plants in the mixture fragmented into smaller, more numerous clumps as grazing intensity increased, but the plants were larger and less numerous than crested wheatgrass plants in comparably grazed pure stands.

In terms of treatment, grazing to a 2-inch stubble height, or approximately 65 percent use of the forage, did not damage the stands for sustained production. Average yield for this treatment was 243 and 144 pounds per acre less than for the 4- and 6-inch treatments, but the pounds per acre of forage grazed by the animals at the shorter stubble height exceeded the loss in stand production. Also, after 12 years of grazing, basal diameters of individual plants were smaller, but both density and the number of tillers produced per square inch of plant were larger than they were on units grazed either to 4- or 6-inch stubble heights (table 8). Although density was greater and tillers more numerous on the 1-inch grazing treatment than on the 2-inch treatment, this level of use was not justified when the average difference in yield of an additional 300 pounds is considered.

Intermediate Wheatgrass

Forage production.—Forage production of intermediate wheatgrass, like that of smooth brome, decreased appreciably under all intensities

of cattle grazing (table 9). Production was 1,600 pounds per acre less in 1960 than in 1950 on units grazed to 4 inches and over 1,300 pounds per acre less on those grazed to 2 or 6 inches. Most of the decrease occurred after 1953 (fig. 4). Prior to that, production of intermediate wheatgrass was comparable to crested wheatgrass both in the mixture and pure stands. By 1960, production averaged from 60 to 70 percent less than crested wheatgrass and the mixture ranges.

The older units grazed to 2 inches showed a reduction in forage production much more quickly than those grazed to 4 or 6 inches. By the third grazing season, forage production was 481 pounds below that on the lightest used units, and remained consistently lower except in 1957. Apparently, the above-average growing-season moisture of 15.62 inches in 1957 had more effect than treatment, and the unit grazed to a 2-inch stubble produced more forage than either of the more lightly grazed units.

TABLE 9.—*Air-dry yields of intermediate wheatgrass under four intensities of grazing, by stubble heights and percent utilization,* [1] *Manitou Experimental Forest, 1950-60*

Year	Yields by grazing intensities (stubble heights)				
	2 inches (new) (66 percent) [1]	2 inches (63 percent) [1]	4 inches (47 percent) [1]	6 inches (33 percent) [1]	Average
			Pounds per acre		
1950	—	1,592	1,954	1,761	1,769
1951	—	572	809	751	711
1952	—	749	1,087	1,230	1,022
1953	—	721	1,630	1,406	1,252
1954	496	282	835	575	547
1955	502	379	937	1,074	723
1956	329	382	582	753	512
1957	618	790	690	690	697
1958	353	153	463	704	418
1959	281	290	493	612	419
1960	200	218	358	418	298
Average	397	557	894	907	689

[1]Percentage of forage removed by weight, averaged for all years.

Forage production on the new [3] 2-inch treatment followed much the same trend as on the original 2-inch treatment units. In 1954, forage production was similar to that for the units grazed to 6 inches. From 1955 on, however, the new 2-inch treatment produced only about half

[3]For simplicity of reference, the 2-inch stubble height treatment superimposed on part of the 6-inch treatment units in 1954 is designated "new 2-inch" treatment to differentiate it from the original 2-inch stubble height treatment.

as much forage as the portions of the units where grazing was continued to the 6-inch level, except for 1957, when production for the two treatments differed by only 72 pounds per acre.

Stand characteristics.—Vegetative and cover changes as a measure of past grazing treatment on intermediate wheatgrass showed that this species was not tolerant of even the lightest intensity of grazing (fig. 6). Vigor and density of intermediate wheatgrass decreased as grazing intensity increased, but this had little influence on cover of invading species (table 10). The areas grazed to 4 inches had the highest density and cover of intermediate wheatgrass, but density and cover of invading species on this treatment were comparable to that of either the "new" or original 2-inch treatments.

TABLE 10.—*Stand characteristics of intermediate wheatgrass and invading native species in 1960 after grazing at four intensities: 2-inch (new) stubble height for 6 years; 2-inch, 4-inch, and 6-inch stubble heights for 10 years*

Grazing treatment (stubble height)	Vigor[1] (Leaf length)	Plant density		Ground cover	
		Intermediate wheatgrass	Invading species	Intermediate wheatgrass	Invading species
	Inches	*No./sq. ft.*		*Percent*	
2 inches (new)	3.9	1.45	5.41	1.50	9.35
2 inches	4.3	1.56	4.49	2.15	10.05
4 inches	4.8	3.19	5.32	3.60	9.50
6 inches	5.1	2.42	4.30	3.15	8.20

[1]As measured by leaf length. Average for 1950-59 except 2-inch (new) treatment, which is average for 1954-59.

Density and cover of intermediate wheatgrass on the areas grazed to 6 inches were more than they were on either of the areas grazed to 2 inches and less than on those grazed to 4 inches. Also, density and cover of invading species were least on the 6-inch treatment. However, density and cover of undesirable species were not much less than for the other intensities of grazing, and invasion by fringed sagebrush was highest. Eighty-two percent of the cover by undesirable species on the 6-inch treatment was fringed sagebrush, compared to 66 percent for the other treatments. Thus, as with smooth brome, even the lightest rate of grazing was damaging to intermediate wheatgrass, and it was not suitable for sustained production and use in the low fertility and drier upland sites of the pine zone.

Russian Wildrye

Forage production.—During the last 3 years of study, Russian wildrye produced more forage under grazing to the 3-inch stubble height than on the other two intensities of use, but through the first 6 years of grazing

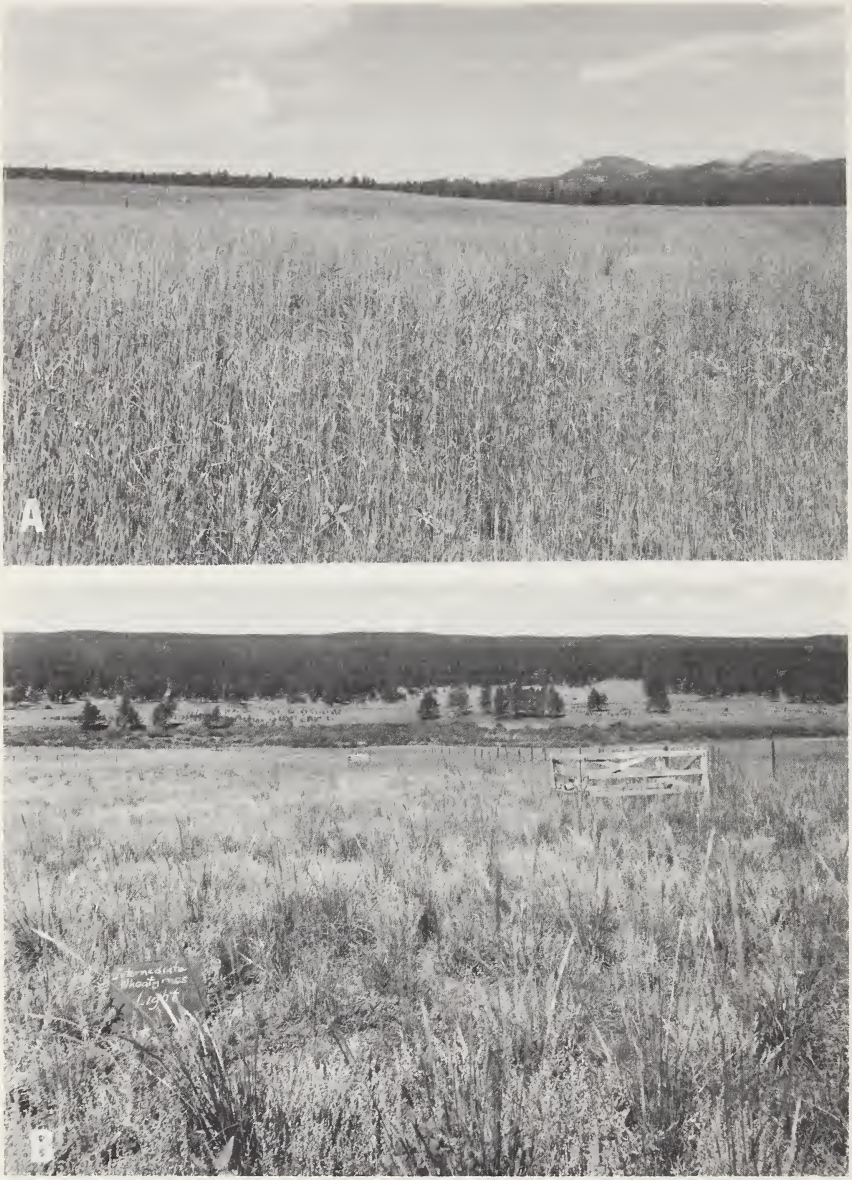

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FIGURE 6.—A, two-year-old stand of intermediate wheatgrass in 1949 before grazing began; B, a stand of intermediate wheatgrass grazed lightly for 5 years. Fringed sagebrush, sleepygrass, trailing fleabane, hairy goldaster, and other undesirable species were conspicuous.

there were *no* large consistent differences in production between grazing treatments (table 11). Through 1956, the units grazed to 1.5-inch stubble height averaged 65 pounds less in forage production than the 3-inch treatment and 121 pounds less than the 4.5-inch treatment. The 4.5-inch and 3-inch treatments varied from year to year in producing the most forage. In 1957, production decreased sharply on the 1.5-inch treatment even though growing-season moisture was favorable. The following year, production decreased more under the 4.5-inch treatment than under 3-inch grazing. This eventual decrease in forage production on the ranges grazed to 1.5 inches and 4.5 inches was brought about by a combination of plant growth in relation to the moisture distribution and differences in utilization by livestock on the grazing treatments.

TABLE 11.—*Air-dry yields of Russian wildrye under three intensities of grazing, by stubble heights and percent utilization,* [1] *Manitou Experimental Forest, 1951-60*

Year	Yields by grazing intensities (stubble heights)			
	1.5 inches[1] (41 percent)	3 inches[1] (20 percent)	4.5 inches[1] (11 percent)	Average
	Pounds per acre			
1951	475	532	510	506
1952	685	839	734	753
1953	1,607	1,620	1,824	1,684
1954	599	526	743	623
1955	770	841	1,008	873
1956	828	997	872	899
1957	610	1,372	1,614	1,199
1958	348	614	392	451
1959	185	754	653	531
1960	276	646	404	442
Average	638	894	875	796

[1]Percentage of forage removed by weight, averaged for all years.

It was common for Russian wildrye plants to yellow at the leaf tips and assume a dormant appearance in dry periods during the grazing season. Green growth resumed, however, following a good summer shower or light showers on consecutive days. Thus, much of the preferred green forage was produced sporadically in small increments throughout the growing season. Russian wildrye, particularly in good moisture years, produced almost 90 percent as much forage in regrowth as it did during the initial growing period, while other species produced 62 percent or less in regrowth.

The regrowth was not segregated by the stubble height method, and this omission was particularly serious for Russian wildrye. Canadian

studies on Russian wildrye under growing conditions similar to those at Manitou Experimental Forest, but which accounted for regrowth, showed that utilization of the total annual growth averaged 65 percent on pastures grazed to an average 3-inch stubble height at the end of the growing season (Campbell 1963). In the present study, utilization was about one-third as much for the same stubble height and a similar disparity in the amount of forage used probably occurred on the other treatments.

With utilization of the regrowth forage throughout a grazing season, forage production over the years was reduced by a gradual depletion of the stands (fig. 7). For both the heaviest and lightest grazed pastures, the depletion resulted from heavy use of the plants. On the units used to 1.5 inches, nearly all plants were heavily and uniformly grazed. On those grazed to 4.5 inches, however, the grazing patterns allowed rank growth to develop, which resulted in decreased palatability of some plants while others carried the grazing load. Many of the large robust "wolf plants" grew additionally in response to summer moisture, but remained ungrazed. Once plants had been grazed, they continued to be grazed heavily, both on initial growth and subsequent regrowth. Thus, the heavily grazed plants were killed or severely reduced in vigor, which reduced production and also provided openings in the stands that were invaded by undesirable species.

Stand characteristics.—Comparable to the other species, vigor of Russian wildrye decreased with each increase in grazing intensity. Differences in leaf lengths were greatest between the units grazed to 1.5 inches and 3 inches with only small differences between 3- and 4.5-inch treatments (fig. 8). When measurements began the first year of grazing, leaf lengths on the units to be grazed to 1.5 inches exceeded those on the 3-inch treatment units and were nearly the same as those for the units to be grazed to the 4.5-inch stubble height. By the next year, initial plant height was slightly less. Generally, plants tended to be shorter each year and were consistently even shorter under the heaviest use rate.

Following 9 years of grazing treatment, differences in density of both the seeded and invading species on Russian wildrye were pronounced between treatments. Russian wildrye averaged 2.19 plants per square foot on the 3-inch treatment compared to 1.84 and 1.60 plants per square foot on 4.5-inch and 1.5-inch treatments (table 12). Invading species increased as Russian wildrye was reduced. The total number of invading plants on units grazed to 1.5 inches averaged nearly twice that on units grazed 4.5 inches and six times that on the units grazed to 3 inches. In both the 4.5-inch and 1.5-inch treatments, undesirable fringed sagebrush and trailing fleabane constituted about 85 percent of all invading plants.

Plant size and tillering characteristics of Russian wildrye followed a similar trend in relation to grazing treatment. On the two lightest treatments, basal diameters of plants averaged about 0.4 inch larger than on heaviest grazed units (table 12). However, the number of tillers produced by plants under a 4.5-inch or 1.5-inch treatment averaged about

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FIGURE 7.—Russian wildrye stands as affected by different intensities of grazing: A, 3-inch treatment; B, 4.5-inch treatment; C, 1.5-inch treatment. The 3-inch treatment remained in good condition, but notice the large percentage of undesirable species, particularly fringed sagebrush, on the 4.5-inch and 1.5-inch treatments. Deterioration in the 4.5-inch treatment was in spots where plants were heavily grazed year after year, while deterioration was general throughout the 1.5-inch treatment.

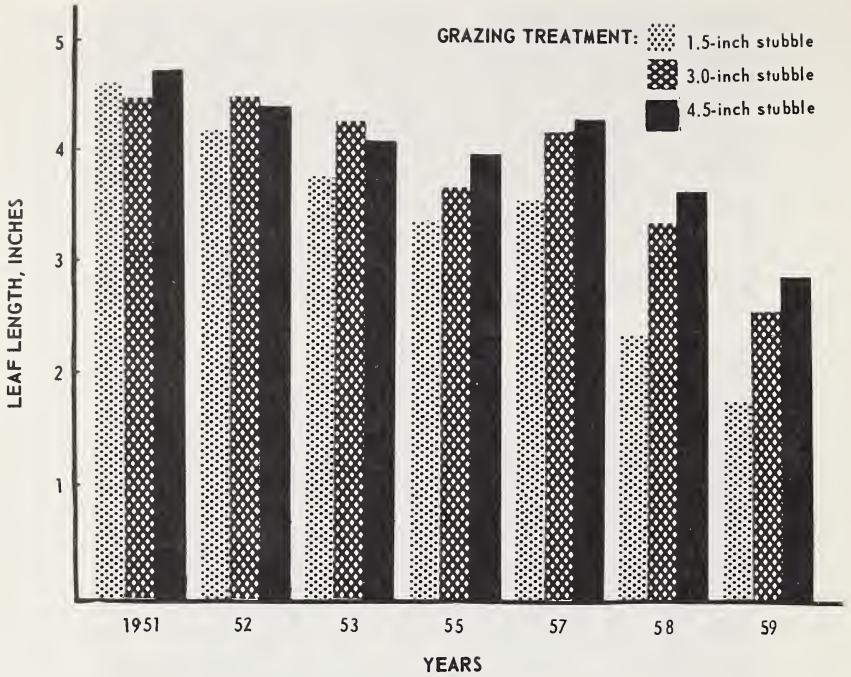

FIGURE 8.—**Leaf lengths of Russian wildrye at beginning of spring grazing as a reflection of plant vigor under different intensities of grazing.**

20 percent fewer than for plants from the 3-inch treatment. These results, like those for forage yields, showed that the lightest grazing of Russian wildrye was not a favorable treatment, but grazing to a 1.5-inch stubble height was most detrimental. Grazing to a 3-inch stubble height was the optimum level of use for sustained production.

TABLE 12.—*Stand characteristics of Russian wildrye and invading native species in 1960 after grazing at three intensities for 9 years: 1.5-inch, 3-inch, and 4.5-inch stubble heights*

Grazing treatment (stubble height)	Russian wildrye			Invading species			
				Fringed sagebrush	Other grasses	Forbs	Total
	Plant density	Basal diameter	Tillers	Plant density			
	No./sq. ft.	*Inches*	*No./sq. inch*	*No./sq. ft.*			
1.5 inches	1.60	2.99	5.76	2.02	0.64	2.23	4.89
3 inches	2.19	3.44	6.35	.58	.07	.11	.76
4.5 inches	1.84	3.38	5.45	1.20	.41	1.01	2.62

Length of Grazing Seasons

With the fixed stocking rates, length of grazing season on seeded ranges varied annually. The amount of grazing paralleled the production of individual species which, in turn, was closely related to growing-season precipitation.

Generally, more days of grazing were obtained from the mixture than from the other species (fig. 9). In 1948, the first year of grazing, the mixture provided 175 consecutive days of grazing. By 1949, it permitted 170 days of continuous grazing; but from 1950 through the end of the study, grazing seasons were usually much shorter or split into a spring-early summer and fall period.

In years such as 1952, 1953, and 1955, when rainfall was more abundant and use was continuous, the seasons were 30 to 45 days longer than in the drier years of 1951 and 1956 when seasons were split. In the extremely dry year of 1954, the mixture ranges provided a total of only 50 days use, which was comparable to the number of days that cattle grazed the other seeded species. However, grazing on mixture ranges was continuous for 140 days in 1957 when precipitation was again abundant, and this was from 20-100 days longer than the grazing period on the other seeded species.

Grazing seasons on crested wheatgrass ranges were about the same length as on the mixture (fig. 9). During 7 of the 12 years of treatment, however, the season was split into periods of spring-early summer and fall grazing, in contrast to only five split seasons on the mixture ranges. In 1950, 1951, and 1952, crested wheatgrass furnished 5 to 10 days more grazing than the mixture, but throughout the remaining years, grazing seasons were from 5 to 40 days shorter than on the mixture. Furthermore, grazing seasons were terminated by mid-August in 3 of the 5 years of continuous grazing.

With the exception of the 1948 season, grazing was less on smooth brome and intermediate wheatgrass than on the other species. Also, their date of range readiness as indicated by leaf lengths was later, particularly during the last several years of study. Initially, smooth brome was ready for grazing as early as crested wheatgrass or the mixture. By 1954, however, it was not ready to be grazed until May 25, 10 days later than these other two ranges. Thereafter, entrance date on this species was from 15 to 20 days behind the other two ranges. The "turn-on" date for intermediate wheatgrass was similar to that for crested wheatgrass and the mixture until 1956; thereafter, grazing readiness was consistently 20 days later. This shorter grazing season and delay in readiness again reflected how forage yields and vigor of smooth brome and intermediate wheatgrass were reduced, even by the lightest level of use tested.

The outstanding feature of ranges seeded to Russian wildrye was their early grazing readiness. In all but 2 years, grazing began on Russian wildrye 5 to 20 days earlier than on any of the other species. For example,

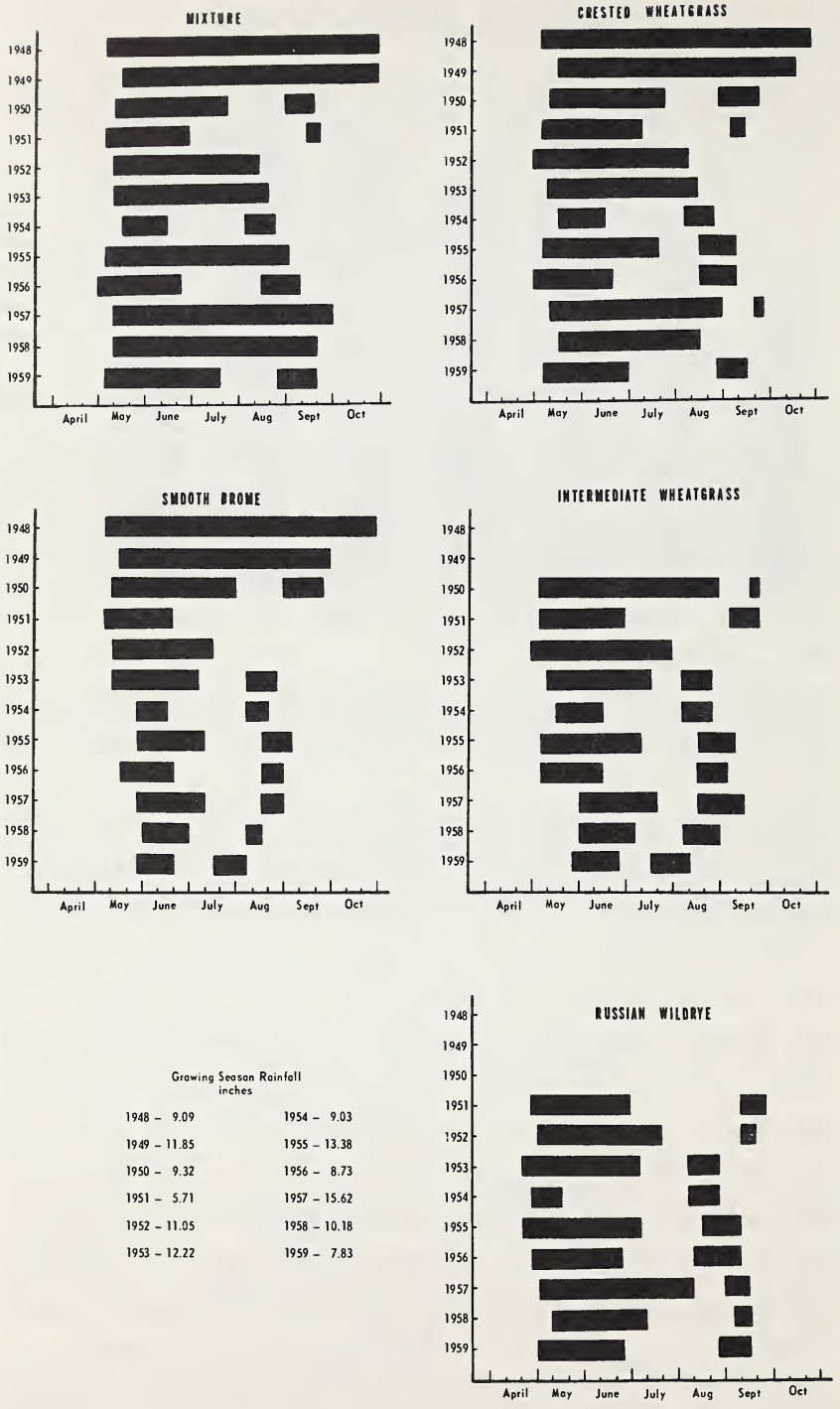

FIGURE 9.—Grazing periods on seeded ranges, Manitou Experimental Forest.

in 1953 and 1955, grazing started April 20, and in 3 other years these ranges were grazed as early as April 25. As shown in figure 9, however, all of the grazing seasons were split, and first-period grazing was terminated on the average after 70 days. Grazing began again as early as August 5 and as late as September 10, and continued for an average of 19 additional days. By comparison, the mixture ranges were grazed an average of 59 days the first part of split seasons, and 20 days the second part. Hence, when it was necessary to divide the grazing season on the mixture range, Russian wildrye range provided more days of grazing. This difference, comparable to the plant analysis data, reflected the regrowth capabilities of Russian wildrye.

For all species, more than twice as many heifer days of grazing per acre were obtained during a favorable growing season such as 1957 compared with a dry season such as 1954. Moreover, the most pronounced increase in heifer days was on the more heavily grazed units (fig. 10). Crested wheatgrass, for example, was grazed from 45 to 48 days longer in 1957 than in 1954 on units grazed to 1- and 2-inch stubble heights, but only 14 days longer on the 4-inch units and 7 days on the 6-inch units. By the final year of treatment, the 1- and 2-inch units provided from 6 to 25 days more grazing than the two lighter grazing treatments. This indicated not only that crested wheatgrass recovers from dry years, but also that sustained animal production occurred at the heavier rates of grazing.

Grazing capacity of the mixture, which in the end was primarily crested wheatgrass, held up well where grazed to 1-inch and 2-inch stubble heights. Grazing increased by 38 days on the 1-inch treatment and 52 days on the 2-inch treatment from the dry year of 1954 to the wet year of 1957. In 1959, the 1- and 2-inch treatments provided from 13 to 23 days more grazing than the 4- or 6-inch treatments. Thus, in terms of animal use, grazing to either 1 or 2 inches was *not* detrimental. Considering the reaction of the plants, however, grazing to a 2-inch stubble height was a better level of use than grazing to the shorter 1-inch level.

Trends in animal days of grazing on smooth brome and intermediate wheatgrass treatments were similar to those for crested wheatgrass and the mixture, but both species showed the effects of any grazing. The heaviest rate of grazing provided more heifer days use in both dry and wet years and also the largest increase in days use from dry to wet years. For example, the number of days use on smooth brome in 1957 increased more than 20 days over that in 1954 on the two heaviest treatments, compared with less than a 1-day increase on the two lightest treatments (fig. 10). On intermediate wheatgrass, there were 26 more days of grazing in 1957 than in 1954 on the older, 2-inch treatment, but only half this amount on the new 2-inch treatment and one-fourth or less on the two lighter treatments. By 1959, both species had noticeably lower grazing capacities than in 1957 which showed the decrease in both forage and

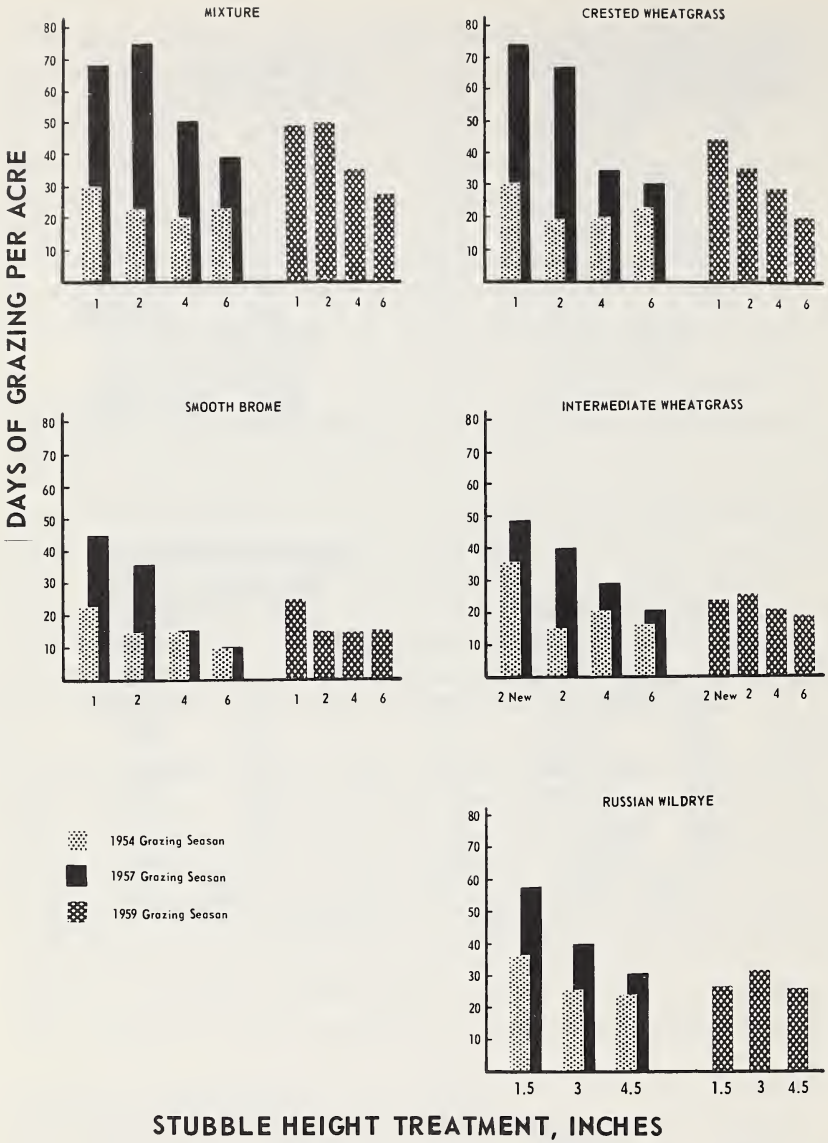

FIGURE 10.—Heifer days of grazing on seeded ranges. Treatments expressed as stubble heights at end of season.

animal production under all levels of use. The units grazed to 1- and 2-inch stubbles were still providing the most days of use, but differences between treatments were smaller and also much less than treatment differences for the other species.

Animal days of use on Russian wildrye followed much the same trend as on crested wheatgrass with respect to moisture and also pointed out

the effects which treatment had on sustained production. The units grazed to 1.5-inch stubble height supported the largest increase in the number of days of grazing between 1954 and 1957. By 1959, however, the 3-inch stubble height treatment provided more days of grazing per acre. As indicated by the plant analysis data, Russian wildrye grazed either to 1.5 or 4.5 inches tended to be depleted rather rapidly after 1957, which would account for 3-inch treatment providing the most days of animal use at the end of the study.

Except for Russian wildrye, where grazing capacity was highest under the 3-inch treatment, more animal days of grazing were obtained at the heavier rates for the other species. The mixture definitely provided the most grazing over the study period. It was followed closely by crested wheatgrass and then Russian wildrye grazed to a 3-inch stubble height. Neither smooth brome nor intermediate wheatgrass maintained good grazing capacities on a sustained yield basis regardless of the intensity of use.

Animal Weight Gains

Daily Gains

The gains made per day by the yearling heifers were closely associated with the length of the grazing season on each of the seeded species and ranged from 1.52 pounds on smooth brome to 1.92 pounds on intermediate wheatgrass (table 13). Daily gains from these two species which were least resistant to grazing, showed an interesting aspect in that gains

TABLE 13.—*Average daily weight gains of yearling heifers grazing seeded ranges at the Manitou Experimental Forest, Colorado, 1948-59*

Year	Daily weight gains				
	Crested wheatgrass	Smooth brome	Mixture	Intermediate wheatgrass	Russian wildrye
			Pounds		
1948	1.41	1.29	1.47	—	—
1949	1.78	1.95	2.00	—	—
1950	1.52	1.32	1.76	1.73	—
1951	1.93	2.12	2.23	2.23	1.51
1952	1.83	2.60	2.03	1.98	1.58
1953	1.45	1.74	1.69	2.10	1.37
1954	1.88	.74	2.31	2.25	1.48
1955	1.66	1.92	1.71	1.99	1.98
1956	1.85	1.59	1.93	2.10	1.77
1957	1.70	1.52	1.68	1.78	1.73
1958	1.03	.96	1.36	1.62	.82
1959	1.96	.55	1.52	1.37	1.50
Average	1.67	1.52	1.81	1.92	1.53

from both were usually inversely associated with forage production and length of grazing season during early years of the study. The largest daily gains were made from 2 to 5 years after grazing began. Smooth brome produced a daily gain of 2.60 pounds in 1952, the highest obtained in the study, but as forage production declined in subsequent years, gains also decreased appreciably. In three of the years after 1952, gain was less than a pound per day and dropped to 0.55 pound per day in 1959, in contrast to gains from other seeded species of 1.37 pounds per day or higher.

Through 1956, intermediate wheatgrass ranges produced an average daily heifer gain of 2.05 pounds per day, but like smooth brome, gains decreased appreciably each year from 1956 through 1959 when they averaged only 1.37 pounds per day. In addition, the intermediate wheatgrass ranges were subjected to several years less grazing treatment than smooth brome or crested wheatgrass ranges, and in view of the depletion of the stands, it is likely that the gains would decrease further with additional years of grazing.

Grazing seasons on both smooth brome and intermediate wheatgrass were usually shorter than on the other species, and it became more and more necessary as the study progressed to split the seasons into two periods (fig. 9). In both the spring-summer and fall grazing periods, the heifers came on the seeded ranges from rather dry forage. In spring, they came from winter pastures or hay to the green, actively growing seeded ranges. As a result, all heifers initially made rapid gains, but those on smooth brome and intermediate wheatgrass reached the established stubble height objectives sooner and were removed before plants became dry or rates of gain slowed. The animals were put back to graze any regrowth in the fall, but again they were grazing green, palatable growth which was conducive to rapid weight gains. As the ranges became severely depleted, particularly on smooth brome in the last 2 years of the study, forage production and the amount of grazing provided were so severely reduced that the animals made only small daily gains. This same type of response occurred in 1954 when dry weather conditions reduced the grazing season to such a short period that the heifers averaged a daily gain of only 0.74 pound per day.

Daily weight gains on the mixture were generally quite good, and more consistent than from any of the other ranges. They averaged only 0.11 pound less than those from intermediate wheatgrass ranges. As on intermediate wheatgrass or smooth brome, daily gains were higher on both the mixture and crested wheatgrass ranges in seasons that were short or split into two periods. In dry years, such as 1951 and 1954 when grazing seasons were short, daily gains on the mixture averaged 2.23 and 2.31 pounds, respectively. The gains were 0.25 pound per day smaller when animals grazed straight through the season. In the wetter years, such as 1953, 1955, and 1957 when animals grazed continuously through the season, gains averaged 0.54 pound per day less than the dry year,

1951. As shown below, daily gains from crested wheatgrass ranges followed the same trend. The gains during years with shorter, split seasons averaged nearly 0.3 pound more per day than when heifers grazed the ranges for a longer single period.

	Season-long grazing	*Split-season grazing*
	(Pounds per day)	
Mixture	1.70	1.95
Crested wheatgrass	1.50	1.79

Gains Per Acre

The average gain per acre from seeded ranges over the 12 years of study ranged from 40.2 pounds for smooth brome to 71.6 pounds for the mixture; the mixture consistently produced the largest per acre gains, (table 14). Unlike daily gains, which were higher in short or split seasons, per acre gains were directly related to forage production and therefore much larger in years of high forage production. For example, gains per acre on the mixture averaged only 12.8 pounds per acre in the dry year of 1954, but 99.8 pounds per acre in 1957. Crested wheatgrass, which ranked next to the mixture, followed the same trend with nearly an eightfold difference in per acre gains for the same 2 years.

Weight gains on both smooth brome and intermediate wheatgrass reflected the downward trend of these ranges from cattle grazing. In early years of the study before the stands were depleted, the per acre gains compared favorably with either the mixture or crested wheatgrass and fluctuated in response to forage production. As the stands deterio-

TABLE 14.—*Average seasonal per-acre weight gains of yearling heifers grazing seeded ranges at the Manitou Experimental Forest, Colorado, 1948-59*

Year	Seasonal per-acre weight gains				
	Crested wheatgrass	Smooth brome	Mixture	Intermediate wheatgrass	Russian wildrye
			Pounds		
1948	82.2	75.4	85.5	—	—
1949	98.3	83.7	126.3	—	—
1950	50.0	35.0	60.1	83.7	—
1951	44.1	35.7	48.7	43.3	38.0
1952	76.3	62.1	77.8	64.8	51.6
1953	56.8	48.0	68.2	63.6	53.8
1954	10.3	2.8	12.8	12.0	10.3
1955	64.5	38.5	86.3	64.4	82.0
1956	54.0	33.2	65.6	58.6	65.6
1957	79.7	37.2	99.8	57.8	67.3
1958	42.0	18.0	65.6	43.7	28.6
1959	52.7	13.4	62.4	31.0	42.4
Average	59.2	40.2	71.6	52.3	48.8

rated, per acre gains generally decreased and by 1959 averaged only 13.4 pounds on smooth brome and 31.0 pounds on intermediate wheatgrass.

Compared with the other species, the per acre gains from Russian wildrye were mediocre. Only in 1956 were per acre gains from this species as high as those from the mixture; for the other years, the gains ranged from about 2.5 to 37 pounds per acre less.

SUMMARY

Abandoned fields in the ponderosa pine zone at Manitou Experimental Forest, Colo., were seeded to crested wheatgrass, smooth brome, intermediate wheatgrass, Russian wildrye, and a mixture of crested wheatgrass, smooth brome, and yellow sweetclover. Yearling Hereford heifers grazed these seeded ranges at several intensities for 9 to 12 years. Grazing on crested wheatgrass, smooth brome, and the mixture was started in 1948, and on intermediate wheatgrass and Russian wildrye in 1950 and 1951, respectively. For each species, measurements were made to determine what effect the different rates of use had on the vegetation, ground cover, and livestock production.

Grazing to established stubble heights on the seeded grasses was the treatment criterion. Except for Russian wildrye, stubble height treatment objectives were 2 inches, 4 inches, and 6 inches. For Russian wildrye, stubble heights were 1.5, 3, and 4.5 inches. In 1953, an additional heavier treatment (1-inch stubble height) was superimposed on parts of the crested wheatgrass, smooth brome, and mixture units grazed to 6 inches, and in 1955 a second 2-inch stubble height treatment was applied on a portion of the intermediate wheatgrass grazed to 6 inches.

Forage yields and the days of grazing on each species differed considerably from year to year. Differences were primarily in response to the amount of summer rainfall received. Between 65 and 90 percent of the variation in forage production of the several species was associated with April-through-August precipitation. Length of grazing season, animal days of use, and weight gain per acre varied with forage yields for each species and their associated treatments.

The mixture of species provided the best sustained forage yields and livestock production. Irrespective of treatment, however, the stands were converted to mostly crested wheatgrass by the end of the study. Grazing to a 2-inch stubble height was the optimum treatment on these mixture ranges. The number of plants and tillers per square inch of crested wheatgrass increased with this heavy use, but plant size decreased. Forage yields and days of grazing per acre decreased also in years of low rainfall, but when precipitation was higher, forage production and grazing capacity recovered to a high level on the 2-inch treatment. In addition, grazing at this intensity was more uniform. Under lighter use, wolf plants developed which remained ungrazed, while adjacent plants were often severely grazed year after year. This resulted in localized depletion of

the stands. Invasion of the stands by undesirable species was approximately the same within all treatments.

Grazing seasons on mixture ranges were often split into a spring-early summer period and a fall period. In such years, daily gains of yearling heifers occasionally exceeded 2 pounds per day. Animal weight gains per acre on the mixture averaged nearly 72 pounds, from 13 to 22 pounds per acre *more* than on range seeded to the individual species.

Crested wheatgrass seeded in pure stands responded to grazing treatment in about the same way as the mixture. It maintained satisfactory yields, plant characteristics, and cover conditions when grazed to a 2-inch stubble height and ranked next to the mixture in length of grazing seasons and livestock gains. Although grazing seasons were comparable to those on the mixture during the first 7 years of the study, they became generally shorter during the last 5 years. Per acre gains, averaging 59 pounds, were lower than those obtained from the mixture during every year of the study, and daily gains were smaller during 10 of the 12 years. Grazing crested wheatgrass to either a 1- or 2-inch level consistently produced more animal days of grazing per acre than the lighter grazing treatments, and these treatments provided the most grazing during years of low growing-season moisture. However, in view of the better yield, cover, and general condition of the stand (particularly increased litter on the 2-inch stubble height treatment), grazing to the heavier 1-inch stubble height does not appear desirable.

The optimum grazing intensity on Russian wildrye was to a 3-inch stubble height. Although utilization appeared rather light, it provided maximum sustained yield and the best cover-density characteristics as well as the best livestock production. Lighter use created very uneven utilization and caused spot deterioration which reduced forage yields. With the heavier rate of grazing, yields were reduced and the stands were invaded by undesirable species.

Heifer gains on Russian wildrye averaged about 1.5 pounds per day and about 50 pounds per acre, which is only mediocre compared to the other species. Russian wildrye was consistently ready to be grazed 5 to 20 days sooner than other seeded ranges, however, and it also provided more days of grazing use than the mixture when seasons were split into spring and fall grazing periods.

Both smooth brome and intermediate wheatgrass stands deteriorated under all levels of use tested, and neither was productive on a sustained yield basis. On all units of either species, forage production was greatly reduced and the density of invading plants was quite high, regardless of treatment. Fringed sagebrush was the primary invader, but other undesirable species such as tumblegrass, trailing fleabane, and hairy goldaster were also abundant. In general, smooth brome and intermediate wheatgrass averaged only 2 to 4 percent cover on all treatments and contributed very little to total cover. Beef production per acre was lower than for the other seeded species except Russian wildrye.

MANAGEMENT RECOMMENDATIONS

The high productive capacities of seeded ranges ,and the seasons during which they can be used to advantage, warrant their incorporation into a livestock management program wherever possible. The following recommendations of grazing intensity, however, apply primarily to areas similar to the ponderosa pine zone of Colorado which is characterized by spring-through-summer rainfall. The response of plants to grazing intensities might be much different in other parts of the western range area where different climatic conditions exist.

A mixture containing crested wheatgrass as the primary species with inoculated yellow sweetclover, plus smooth brome or intermediate wheatgrass as secondary species, is recommended for sustained forage and livestock production..Although sweetclover can be expected to die out within a few years, apparently its initial influence on added production makes it worth including in new seedings. Smooth brome and intermediate wheatgrass are also recommended in mixture plantings even though neither species individually held up well under any grazing intensities studied. In early years of the stands, both species provided good daily gains, per acre gains, and high grazing capacities which would justify their inclusion in mixture plantings. As they die out, daily animal gains may decrease, but overall yield of forage and beef will probably be greater than on crested wheatgrass seeded in pure stands. This recommendation is supported by measurements of smooth brome on the mixture in the present study and from results for intermediate wheatgrass in a mixture in Canadian studies under comparable climatic conditions (Campbell 1961, 1963).

Grazing of mixture ranges can begin in the spring when maximum leaf lengths average approximately 4 inches on the crested wheatgrass plants. These ranges should then be stocked heavily enough to make uniform use of the available forage. Grazing to a 2-inch stubble height, or approximately 65 percent use of the forage by weight, accomplishes this purpose. Some reduction in ground cover, particularly litter, can be expected at this rate, but invasion by undesirable species will not be much greater than from grazing at a llghter intensity. The advantages of a good level of forage production, more uniform utilization, and greater animal gains per acre, make grazing to a 2-inch stubble height preferable to grazing at a lighter rate *unless* the additional cover is needed for erosion control and watershed protection purposes.

In an operation where the principal forage requirement is for very early feed, Russian wildrye may be seeded in pure stands with the realization that animal weight gains will usually be smaller than on ranges seeded to a mixture. Because of its early growth, however, this species will provide forage before other seeded species are ready for use. Grazing to approximately a 3-inch stubble height is recommended for Russian wildrye, which should avoid development of ungrazed wolf plants and

eventual overgrazed local areas.

Smooth brome or intermediate wheatgrass are *not* recommended for seeding in pure stands on abandoned fields or the dry upland sites of the ponderosa pine zone.

COMMON AND SCIENTIFIC NAMES OF SPECIES MENTIONED

Grasses

Agropyron cristatum (L.) Gaertn.	crested wheatgrass
A. intermedium (Host) Beauv.	intermediate wheatgrass
A. trachycaulum (Link) Malte	slender wheatgrass
Bromus inermis Leyss.	smooth brome
Elymus junceus Fisch.	Russian wildrye
Koelaria cristata (L.) Pers.	Junegrass
Muhlenbergia montana (Nutt.) Hitchc.	mountain muhly
Schedonnardus paniculatus (Nutt.) Trel.	tumblegrass
Sitanion hystrix (Nutt.) J. G. Smith	bottlebrush squirreltail
Stipa robusta (Vasey) Scribn.	sleepygrass

Forb, Shrub, or Tree Species

Artemisia frigida Willd.	fringed sagebrush
Chenopodium album L.	lambsquarter
Chrysopsis villosa (Pursh.) Nutt.	hairy goldaster
Erigeron flagellaris A. Gray	trailing fleabane
Helianthus annuus L.	common sunflower
Melilotus officinalis (L.) Lam.	yellow sweetclover
Pinus ponderosa Laws.	ponderosa pine

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LIST OF FIGURES

LIST OF TABLES

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